Current status and future prospects of optical communications technology and possible impact on future BDEC systems

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One of the key issues in enabling the convergence of Big Data Analysis and High Performance Computing (HPC) is the bandwidth of inter-node communications. Wide bandwidth optical interconnections with optical circuit switching are a promising solution to drastically improve the bandwidth without consuming much power. Here, we summarize the current status and future perspectives of both optical interconnection and optical circuit switching technologies that can be used in an HPC system.

For optical interconnections, usually single or a small number of direct modulation channels are used for HPC systems and data centers, resulting in around 100Gbps per fiber. However, even though the bandwidth of a single optical channel is at most 25~100Gbps, polarization division multiplexing and wavelength division multiplexing (WDM) allow us to bundle tens of channels on a fiber. Using dense-WDM (DWDM) in future HPC systems, bandwidth on the order of tens of Tbps can be realized using a single fiber. Heat and cost of DWDM light sources have been barriers in introducing DWDM in an HPC system. NTT has proposed a wavelength bank (WB) or optical comb source in 2005 [1], which is a centralized generator of wavelengths for DWDM. The wavelengths are distributed to computing nodes through optical amplifiers, thus eliminating the need for light sources at each computing node. The distributed light is de-multiplexed into individual wavelengths, modulated, multiplexed again, and transmitted from each computing node. AIST has proposed to use a WB with a silicon photonics modulator and implement them in data centers and HPC systems [2]. Silicon photonics optical circuits can be used for whole light wave processing, including modulation, at a computing node. Using WB and silicon photonics, a total of 10Tbps bandwidth can be achieved in a single fiber for inter-node communication in HPC systems.

If DWDM signal switching is performed using electrical switches, it will require a large physical space and will consume large amounts of power due to the high bitrate; thus it will not be realistic to use in HPC systems or datacenters. If switching is done optically, power consumption is not proportional to the bitrate, and switching can be done with very low power consumption with more than 10Tbps DWDM signal in one bundle. However, optical switches have some disadvantages such as slow switching speed and limited number of ports (degrees). The following table shows the specifications of optical switching technologies currently available. Given the current status of research in this area, we expect only moderate progress in the number of ports and switching speed to be made in the future.

	MEMS based	PLC based	Silicon photonics	WSS	AWG-R based	SOA based fast multicast switch
Technology	MEMS	PLC	Silicon waveguide	Mostly LCOS	PLC and tunable laser	SOA
Type	Fiber switch	Fiber switch	Fiber switch	Wavelength switch	--	--
Port Count	192x192 (C.A.)*	32 x 32 16 x16 (C.A)*	32x32	1x20 (C.A.)* 1x40	720x720	8x8
Port Bandwidth	Ultra wide (tens of THz)	Fairly wide (more than 5 THz)	Fairly wide (more than 5 THz)	Fairly wide (more than 5 THz)	25 - 100GHz (Tradeoff with the port counts)	--
Physical Size	Can be large	110 x 115 mm (chip size)	11 x 25 mm (chip size)	--	--	--
Insertion Loss	About 3 dB	6.6 dB	About 20dB	3 - 6 dB	--	--
Crosstalk	Can be very small	< -40dB	< -20dB	< -40dB	--	--
Switching Time	Tens of milliseconds	< 3ms	30 microseconds	Tens of milliseconds	Hundreds of microseconds (Depends on TLS)	< 10ns

With the ever-increasing demands of big data on infrastructure, design of future HPC systems should carefully consider the current status and prospects of optical communication technology, especially in the areas of bandwidth and power consumption.

[1] Masahito Tomizawa, Jun Yamawaku, Yoshihiro Takigawa, Masafumi Koga, Yutaka Miyamoto, Toshio Morioka, and Kazuo Hagimoto Terabit LAN with optical virtual concatenation for Grid applications with super-computers, OFC/NFOEC Technical Digest. Optical Fiber Communication Conference 2005. , paper OThG6

[2] Takashi Inoue, Takayuki Kurosu, Kiyo Ishii, Haruhiko Kuwatsuka, and Shu Namiki , Exabit Optical Network Based on Optical Comb Distribution for High-Performance Datacenters: Challenges and Strategies, Frontiers in Optics 2015 OSA Technical Digest (online) (Optical Society of America, 2015), paper FTh3C.3